INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY

POLICY MEASURES TO COMBAT ENERGY POVERTY AMONG LOW-INCOME HOUSEHOLD GROUPS IN SERBIA: A MULTIDISCIPLINARY ANALYSIS

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EXECUTIVE SUMMARY

Energy poverty, understood as a situation in which one household is not able to afford essential domestic energy services, is a phenomenon spread throughout Europe. In the following study, the Republic of Serbia will be considered specifically. The latter is, as other Western Balkan countries, affected by inefficient dwellings and housing appliances. These are characterised by outdated technological devices that further hamper their energy efficiency and carbon footprint. Additionally, the majority of the buildings in Serbia are outdated and need to be refurbished. This is aggravated by the fact that the residential sector represents the largest final consumer of energy in the country. Typically, residents living in energy inefficient households present below average disposable incomes. Similarly, low-income groups are more subject to energy poverty. This hints to the "vicious cycle of energy poverty", where households presenting low disposable incomes eventually end up spending more on energy since these are unable to afford efficient dwellings and/or house appliances.

Considering the previously mentioned "vicious cycle of energy poverty" and the fact that low-income groups are more affected by energy poverty, it was decided to focus on this specific strait of society. Additionally, being a contracting party of the Energy Community Treaty, the Republic of Serbia adheres to implementing EU climate directives (sustainable goals) in the country. Stemming from this, the following Main Research Question was delineated, around which the whole research process was structured: Which energy policy strategy should the Ministry of Mining and Energy implement in Serbia as to achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups?

The proposed policies presented elements, and were analysed, both from a qualitative and quantitative perspective. On the one hand, the institutional, legal, and policy framework in the field of energy in Serbia was analysed, as to ensure the proposed policies were politically and socially feasible. On the other hand, the technical effectiveness in terms of final energy consumption and expenses reduction was also considered. To that end, a MS Excel linear and static simulation model was employed. It was found that performing a simulation-backed analysis of the available policy strategies in Serbia, delineating an optimal one to reduce energy poverty levels and improve household energy efficiency among low-income groups in Serbia, satisfying the sustainable targets set by the European Commission, represented a knowledge gap in the literature.

Three main policies were delineated corresponding to three different simulated scenarios. Namely, (i) the implementation of an emissions trading scheme extended as to also include the residential sector; (ii) the phasing out of heating oil and fossil fuels in 2030, followed by natural gas in 2040; (iii) the implementation of Minimum Energy Performance Standards (MEPS) in the residential sector. The latter resulted as the best performing policy, presenting the highest reduction in final energy consumption and expenses, resulting politically and socially feasible, delivering a positive social impact among low-income households in Serbia.

1. INTRODUCTION

As recognised in the European Green Deal, across the European Union, 50 million people do not have the capacities and opportunities to have access to indoor thermal comfort (European Commission, 2019). Such a situation, where households are incapacitated to present adequate levels of energy services, can be defined as energy poverty. Whereas this inability to afford energy services stems from different causes pertaining to different fields, a clear path dependency between *energy poverty* and *household energy efficiency* can be observed (Thomson et al., 2017). The latter essentially represents the ratio between the needed energy to power the household and the energy output generated (World Bank and IEA (International Energy Agency), 2013).

The UN has placed energy efficiency as one of its Sustainable Development Goals. Namely, doubling the energy efficiency global rate of improvement by 2030 is Target 7.3 (United Nations, 2021). Similarly, as part of the renewed Green Deal, the European Commission has set an improvement of at least 36% in energy efficiency as one of the key targets to be achieved by 2030 (European Commission, 2021b). Inefficient ways of gathering, producing, and distributing energy impact different straits of society in different ways; low-income groups being the most affected ones (Deller & Waddams Price, 2018). Inefficient energy production and distribution entails higher costs, which often hampers the affordability of the latter. Ensuring universal access to reliable, modern, and affordable energy services is another Sustainable Development Goal, namely Target 7.1 (United Nations, 2021).

The Republic of Serbia is, unfortunately, particularly characterised by energy poverty and low household energy efficiency. The latter is mainly due to inefficient heat generating house appliances, low insulation, and household energy losses. In Serbia, 55.9% of households utilise solid fuel as their main resource for heating (Statistical Office of the Republic of Serbia, 2020). Additionally, 58.9% of households did not present central heating installations (Macura, 2017). The residential sector is the largest consumer of energy in Serbia, representing 34% of total final energy consumption in the country (Odysse Mure, 2021). Thus, to reduce energy poverty in Serbia, an improvement in terms of energy efficient heating devices is required. Substituting outdated heating systems with newer better-performing ones outside the realm of natural gas, oil and coal represents an opportunity. In fact, such an operation could greatly improve figures related to energy poverty in the country, displaying potential to massively increase savings while at the same time presenting short payback periods on investments (Young & Macura, 2020). This change to efficient heating must happen in tandem to a better insulation and refurbishment of households.

Stemming from in-depth research regarding the Serbian energy policy framework, household energy efficiency and energy poverty status quo, different policies will be delineated and proposed to tackle the previously mentioned issues. These will be tested by running a static and linear modelling simulation. The obtained quantitative results will be considered and utilised as technical backing with regards to preferring one policy over the other. Nonetheless, in addition to the envisioned degree to which the proposed policy would reduce final energy consumption and expenses, qualitative factors will also be examined, such as the political and social feasibility, and the social impact each policy would entail. To conclude, the best performing policy is expected to reduce final energy consumption and expenses, being both politically and socially feasible, presenting sustainable and affordable implementation costs, diminishing energy poverty and thus bringing a positive social impact among low-income households in the Serbian residential sector.

Energy poverty has been gathering increasing attention both at an academic and political level throughout the last year, exacerbated by the current European energy crisis. Nonetheless, symptoms of energy poverty throughout Europe were already visible prior to the crisis. Various countries throughout Europe were starting to delineate policies to tackle energy poverty within the residential sector. Bouzarovski & Burbidge (2021) had summarised and analysed the main policies set out in (mostly) Western countries to tackle energy poverty within the private rented sector. The report stems from the findings of the ENPOR consortium, funded by the EU, which aims to design and implement policies to help decision-makers understand and tackle energy poverty. Nonetheless, Serbia was not part of the countries analysed by the latter. Similarly, Rogulj et al. (2022) investigated how different delineated policies would hinder energy poverty in various EU member states. This study was taken as a reference when performing linear simulations. Finally, the present report reiterates, summarises, and updates the findings previously obtained (Peretto, 2022).

2. ACADEMIC CONTEXT

Energy poverty is a socioeconomic issue that affects different segments of society in different ways (Bouzarovski, 2018; Deller et al., 2021). Household energy efficiency represents a key element in combating energy poverty, which is also demonstrated by the directives outlined by the European Commission (Deller, 2018; European Commission, 2021c). No single best indicator for measuring energy poverty and household energy efficiency was found in the literature (Deller, 2018; Tirado Herrero, 2017; Waddams Price et al., 2012). Depending on the country being analysed, different indicators might be preferred, although it is good practice to consider both objective and subjective indicators in general (Bouzarovski, 2018; Tirado Herrero, 2017). The Western Balkans region is characterised by high levels of energy poverty and inefficiency, and so is Serbia (Bouzarovski & Tirado Herrero, 2017; Serra, 2016). There is a lack of coordination between different institutional bodies in the country in delineating structured plans and policies aimed at reaching energy transition goals (Energy Community, 2021; Young & Macura, 2020). Nonetheless, Serbia is one of the contracting parties of the Green Agenda for the Western Balkans and as such has declared its willingness to achieve sustainable goals delineated by the European Commission (European Commission, 2020).

2.1. Research Questions

Performing a simulation-backed analysis of the available policy strategies in Serbia, delineating an optimal one to reduce energy poverty levels and improve household energy efficiency among low-income groups in Serbia, satisfying the sustainable targets set by the European Commission, represents a knowledge gap. Therefore, the present work aims to analyse and resolve such knowledge gap. To do so, a Main Research Question will be delineated, around which the whole report will be structured. The answer to it will also represent the final recommendation to the Ministry of Mining and Energy (Section 7). Namely, the Main Research Question is the following:

Main Research Question: *Which energy policy strategy should the Ministry of Mining and Energy implement in Serbia as to achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups?*

To facilitate the understanding and answering of the latter, four Sub-research Questions (SRQs) were delineated to guide the research process:

SRQ1: *Which energy policies, measures, and targets are currently being employed and which future ones are envisioned?*

SRQ2: *What is the current status quo concerning household energy efficiency as well as energy poverty in low-income groups in Serbia, how are the latter defined and which indicators should be chosen to measure these?*

SRQ3: *Following a linear simulation, which policy mix (strategy) would result as optimal for Serbia to achieve the sustainable goals established by the European Commission?*

SRQ4: *Which feasible policy instruments/mechanisms are available for Serbia to improve household energy efficiency as well as energy poverty in low-income groups and how much extra costs would this entail?*

3. ENERGY POLICY FRAMEWORK IN SERBIA

3.1. Current Serbian Energy Policy Framework (2020-present)

The Republic of Serbia has made important improvements in the field of energy efficiency and poverty in the last decade by implementing several directives, decrees and initiatives. More recently, in April 2021, the Serbian National Assembly adopted two new laws as well as amendments to two existing laws in the field of energy (Spasić, 2021a). The two new laws are respectfully: the *Law on Renewable Energy Sources* and the *Law on Energy Efficiency and Rational Use of Energy*. Whereas the amendments were applied to the *Law on Energy* and the *Law on Mining and Geological Research*. These innovations in the Serbian legal framework will be further discussed in the following subsection.

Aimed at mitigating climate change and improving sustainability, the Law on Renewable Energy Sources regulates extensively the most significant aspects related to the use of renewable energy sources (RES). The new Law adds more detail and structure concerning the regulation of RES, which were previously regulated by Section V of the Energy Law (Djordjević & Vujošević, 2021). As the name suggests, the Law aims to promote and fasten the transition to renewable energy by stimulating investments in the sector. This is done by providing two incentive systems, namely: market premiums and feed-in tariffs for small projects. The former can be seen as a form of operational state aid (Djordjević & Vujošević, 2021). Expressed in eurocents per kWh in the auction process, the premium is a supplement to the market price of electricity that will be delivered to the market by the premium users. This will be paid monthly based on the amount of electricity delivered to the grid by the plant. The right to the premium can be acquired by participating in auctions conducted by the devoted Ministry (Djordjević & Vujošević, 2021). Similarly, the right to a feed-in tariff is also awarded by the Ministry through auctions. The tariffs apply only for power plants and wind plants with a capacity below 500 kW and 3 MW respectively, and demonstration projects (Djordjević & Vujošević, 2021). The Law sets a legal framework allowing end-users to produce their own energy from RES and thus becoming *prosumers* (e.g., consuming energy produced from rooftop solar panels). The energy produced “in-home” by prosumers can also be stored or delivered as electricity surplus to the grid, which will lead to either a monetary compensation or a reduction of the upcoming electricity bill (Djordjević & Vujošević, 2021). In addition, prosumers are allowed to form so called *renewable energy communities*, recognised as legal entities, constituted by voluntary members willing to produce energy from RES. Finally, the Law also introduces strategic partnership schemes between public and private entities devoted to increase investments in building plants and promoting innovative technologies utilising RES (Djordjević & Vujošević, 2021).

The Law on Energy Efficiency and Rational Use of Energy aims to improve the whole energy sector, by ameliorating the general efficiency, thus reducing waste and the climatic impact of the energy sector, but also increasing economic competitiveness and reducing energy poverty. The Law harmonizes the Serbian regulations in the energy sector with EU directives. Energy efficiency policy and measures are introduced, regulating the financing of and incentives in the energy sector to promote a more efficient use of the latter (Aleksić, 2021). The Law implements an energy management system, where a set of measures and regulations are present to monitor and analyse the consumption and activities of energy within the system. The contributors and members of such system will be chosen by the Government, and these will comprise both private companies and public ones, including city municipalities with more than 20,000 inhabitants as well as local self-government units (Aleksić, 2021). The Law imposes several obligations to the contributors of the system, such as appointing energy managers and monitoring the energy consumption. Failure to adhere to these measures will result in fines (Aleksić, 2021). Similarly to the Law on RES, subsidies will be provided to both individuals and legal entities, in this case to promote the installation of efficient gas and biomass boilers, carpentry, and isolation systems. Lastly, the Law deals with energy labelling and sets requirements for labelling devices as eco-design (Aleksić, 2021), as improving the labelling of products in the market can highly improve the efficiency of household electrical appliances.

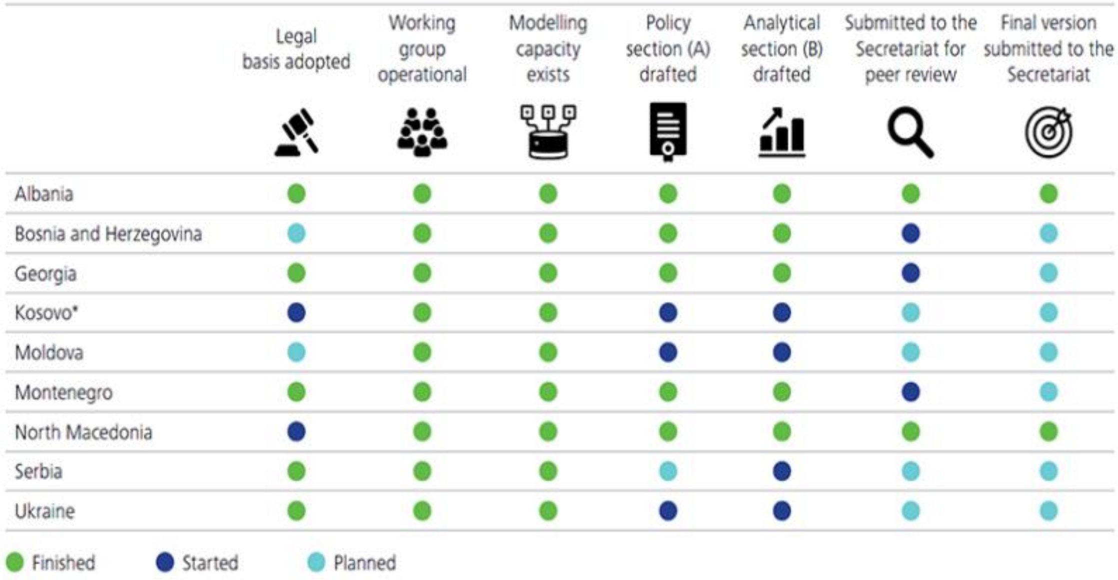
3.2. Future Envisioned Serbian Energy Policy Framework

The Republic of Serbia has developed and implemented various tools to improve the energy sector and accordingly has outlined several targets, more or less objectively defined, to be achieved in the future. These tackle various aspects and industries of the sector and are delineated in accordance with both national requirements but also EU directives. The vision of the Ministry of Mining and Energy is one of an energy-safe and climate-neutral economic development of the country, allowing it to be the regional leader in energy production (Ministry of Mining and Energy, 2022a). As mentioned previously, four new laws have been implemented in 2021 to establish a legal framework in which to act and improve the energy sector; in addition to these, a *Law on Climate Change* was also adopted to fasten the implementation of national low-carbon development strategies (Ministry of Mining and Energy, 2022a). An investment plan for projects concerning energy and mining was defined by the Ministry, with more than 35 billion euros being devoted to it, of which 21 billion focused on the development of hydropower, solar and wind power plants (Ministry of Mining and Energy, 2022a). Decarbonisation is indeed one of the pillars of the Serbian strategic development of its energy sector, with achieving carbon neutrality and reducing net emissions to zero by 2050 as one of its main targets (Ministry of Mining and Energy, 2022a). Nonetheless, Serbia has not introduced an emissions trading system (ETS) in the country; no regulating mechanism for the calculation of the price of CO_2 is currently available; and no taxing system for CO_2 has been established (Ministry of Mining and Energy, 2022a).

To achieve carbon neutrality by 2050, all aspects of the energy sector need to be improved and updated regularly. As a short-term objective, the Ministry of Mining and Energy has set to increase the production, especially from RES, of electricity and heat as to facilitate the energy transition and reduce consumption in the industry and transport sectors (Ministry of Mining and Energy, 2022a). With regards to the production of thermal energy, replacement of current fossil fuel boiler plants with more efficient ones, which would be possible to adapt in the future as to run on alternative forms of fuel such as hydrogen, is considered as a viable short-term solution (Ministry of Mining and Energy, 2022a). In fact, the whole distribution network of thermal energy could be replaced by more efficient and advanced boiler rooms. The transition to new systems in the field of thermal energy allowing for an economically sustainable functioning of the network can be achieved by applying the Decree on the formation of the price of heating (Ministry of Mining and Energy, 2022a). In addition, the share of RES in district heating will need to be inevitably increased, developing district heating systems fully harmonized with grids and networks of other fuels such as gas. Incentives for producing thermal energy from heat pumps, solar energy, biomass and geothermal energy are planned to be implemented (Ministry of Mining and Energy, 2022a).

The share of renewables in energy consumption will have to be increased throughout all areas of the energy sector. The Ministry of Mining and Energy has set a as a target the achievement of a minimum of 49.6% share of RES in gross final energy consumption by 2040 (Ministry of Mining and Energy, 2022a). The current Minister of Mining and Energy, Zorana Z. Mihajlović, stated that achieving a 50% share of RES in national energy production by 2050 was another goal of the Ministry (Ministry of Mining and Energy, 2021c). To achieve these targets, the general efficiency of the whole sector will need to be improved. Improving the energy efficiency of dwellings by providing incentives is seen as a short-term solution which could reduce excess energy consumption already by 50% (Ministry of Mining and Energy, 2022a). Specific programmes devoted to the energy rehabilitation of public buildings at a local level are envisioned to reduce energy consumption by approximately 40% in the short-term (Ministry of Mining and Energy, 2022a). As a long-term solution, the Ministry envisioned expanding incentives as to promote also the usage of RES for household needs and thus rehabilitate starting from 2021 up until 2050 a living space area of approximately 100 million square meters. This would result in electricity savings of up to 500,000 MWh annually and a reduction of 37% of CO_2 emissions compared to 2020 levels (Ministry of Mining and Energy, 2022a).

The Ministry of Mining and Energy has set various targets, both short-term and long-term, in different areas of the energy sector. To achieve these, detailed plans, strategies and budgets need to be delineated. The last strategy for the development of the energy sector was outlined by the Ministry in 2016 for the period by 2025 including projections until 2030 (Ministry of Mining and Energy, 2016). The new development strategy for the period until 2030 with projections until 2050 is still being drafted as this article is being written (Ministry of Mining and Energy, 2022a). As agreed in the Energy Community Treaty and following the new EU directives, every contracting party is requested to submit a National Plan for Energy and Climate (NECP) defining the set targets and measures to reduce GHG emissions, improve energy efficiency and increase the share of renewables in the energy sector. Serbia is still in the process of drafting its NECP, even though having planned and announced to deliver it by the end of November 2021 (Spasić, 2021b). Unfortunately, Serbia is behind other contracting parties in the drafting of its NECP, as can be seen in Figure 1. On July 27th 2022, Serbia presented the preliminary goals for the NECP being developed. These include: a 40.3% reduction of GHG emissions in 2030 compared to 1990 levels; a 41% share of RES in gross final energy consumption in 2030; and a share of 50.9% of RES in heating and cooling applications in 2030 (Ministry of Mining and Energy, 2022b).



	Legal basis adopted	Working group operational	Modelling capacity exists	Policy section (A) drafted	Analytical section (B) drafted	Submitted to the Secretariat for peer review	Final version submitted to the Secretariat
Albania	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Bosnia and Herzegovina	⚪	🟢	🟢	🟢	🟢	🔵	⚪
Georgia	🟢	🟢	🟢	🟢	🟢	🔵	⚪
Kosovo*	🔵	🟢	🟢	🔵	🔵	⚪	⚪
Moldova	⚪	🟢	🟢	🔵	🔵	⚪	⚪
Montenegro	🟢	🟢	🟢	🟢	🟢	🔵	⚪
North Macedonia	🔵	🟢	🟢	🟢	🟢	🟢	🟢
Serbia	🟢	🟢	🟢	⚪	🔵	⚪	⚪
Ukraine	🟢	🟢	🟢	🔵	🔵	⚪	⚪

🟢 Finished 🔵 Started ⚪ Planned

Figure 1: Overview of the progress made by contracting parties in developing National Plans for Energy and Climate (July 2022) (Energy Community, 2022a).

4. MULTIDISCIPLINARY LINKAGES BETWEEN ENERGY POVERTY AND LOW-INCOME HOUSEHOLDS IN THE SERBIAN CONTEXT

4.1. The Social Context of Energy Poverty and Household Energy Efficiency in Serbia

In Article 3 of the Law on Energy Efficiency and Rational Use of Energy, energy poverty is defined as a situation resulting from a "combination of low household income, large expenditure of available income on energy and insufficient energy efficiency" (Ministry of Mining and Energy, 2021b). This definition is quite focused on the economic aspects of the issue rather than the more societal ones. A more comprehensive definition was suggested in Serbia, defining the latter as a state in which households do not have the necessary means to afford the required amount of energy as to live a healthy and dignified life, in a way that does not harm other households or larger communities (RES Foundation, 2021). This definition is rather similar to the one proposed by Bouzarovski which is adopted in the following study; namely a situation occurring when "a household is unable to secure a level and quality of domestic services – space cooling and heating, cooking, appliances, information technology – sufficient for its social and material needs" (Bouzarovski, 2018, (p.1)). Other definitions found in the literature were not always applicable to Serbia specifically. For example, applying the 10% threshold proposed by Boardman (1991), the majority of Serbian households would be found to be energy poor as, on average, these spend 12.4% of their total income on energy expenditures (RES Foundation, 2021). Being a socioeconomic issue, energy poverty presents various ramifications. The most concerning ones for the present study will be analysed in the following paragraphs specifically applied to the Serbian context, where the close relationship between household energy efficiency and energy poverty will be further illustrated.

Energy inefficient buildings highly affect energy poverty, as these entail higher energy expenses and consumption. There are various aspects that hinder the efficiency of dwellings. Nonetheless, older buildings tend to present lower energy efficiency levels compared to newer ones, especially block buildings built during the Socialist period of the country. In Serbia, 47.5% of the dwellings were constructed between 1971 and 1990, 28.9% between 1994 and 1970 and only 19.4% after 1990 (Statistical Office of the Republic of Serbia, 2020). The need to renovate buildings in Serbia was also recognised by the Ministry of Construction, Transport and Infrastructure (2019). In addition, it was found that 8.5% of buildings in Serbia were illegal and 13.5% were in the process of being legalized (RES Foundation, 2021). It must be noted that Serbia has increased investments in the buildings sectors, however it is estimated that an extra 1636 million euros of investments are needed to reach energy efficiency goals (Energy Community, 2021). Similarly to buildings, energy inefficient appliances also increase energy expenses and thus affect energy poverty. Whereas the utilisation of such devices is also a result of poverty and inability to afford better appliances, it is also due to a lack of information concerning potential benefits of improved devices. It is estimated that only around 20% of users of inefficient heating devices in the Western Balkans are aware of the benefits related to upgrading their devices (RES Foundation, 2022). These inefficient heating devices are usually solid-fuel or wood-fired stoves. Devices that burn wood for heating are carbon-neutral and considered as utilising biomass, nonetheless in an inefficient manner.

Energy poverty affects different straits of society in different ways. In 2019, 9.9% of the total population in Serbia was unable to keep its home adequately warm (Eurostat, 2022). In 2020, this number was reduced by 0.4 percentage points to 9.5%, suggesting a minimal improvement. However, when analysing the poorer straits of society (below 60% of median equivalised income) the situation changes. In 2019, 19.7% of the population could not keep its home adequately warm; in 2020, this number increased to 26.2% (Eurostat, 2022). This represents quite a substantial increase, which is not seen if considering the population as a whole. This goes to show how people on the lower side of the equivalised income line are more affected by energy poverty, as seen also in the literature (Deller & Waddams Price, 2018; Deller et al., 2021). Indeed, poorer people will tend to live in old and inefficient buildings, utilise outdated and inefficient heating devices and generally be less aware of the benefits and possibilities related to modernising their devices. For this reason, the following study focuses on low-income household groups.

4.2. Available Policy Measures to Lessen the Energy Burden

Serbia has recognised the need to protect most vulnerable energy consumers in line with the requirements and regulations delineated in the third EU Energy Package (Ban et al., 2021). Several policies and directives attempting to protect vulnerable consumers have been implemented, mostly focused on electricity and gas consumers. Various acts and directives have defined vulnerable consumers in different ways. However, there is no definition of low-income groups in the context of access to essential services, with the latter also missing a definition (Baptista & Marlier, 2020). This does not mean that there are no existing support measures that people can access based on specific eligibility conditions, but rather that these are defined differently. For example, services such as the Financial Social Assistance (FSA) and child benefits are present in Serbia (Baptista & Marlier, 2020). Nonetheless, no protection mechanisms and/or schemes to alleviate the causes and dimensions of energy poverty, such as the ones described in the previous section, have been implemented (Ban et al., 2021). These should be present in the National Energy and Climate Plan (NECP), which is still under development (Section 3.2).

Reduced tariff mechanisms to help alleviate the financial burden related to access to energy services for poorer people are present in Serbia, mainly focused on electricity and gas (Pejin Stokić & Bajec, 2020). These are present both at a local and national level, however here only the latter will be analysed. In order to qualify for such tariffs, households need to match a number of requirements. Recipients of the FSA or child benefits are considered directly eligible, whereas other conditions are set for other categories of vulnerable consumers (Pejin Stokić & Bajec, 2020). The three factors analysed to determine the eligibility of consumers are the size of the household, its monthly income and monthly consumption of electricity and gas. The monthly income ceiling for a single-person household to be eligible for reduced tariffs is 125 EUR (14,645 RSD) (Pejin Stokić & Bajec, 2020). This number increases (non-linearly) depending on the size of the household. For comparison, the threshold defined in 2018 for a single-person household to be defined as "at-risk-of-poverty" was a monthly income of 141.40 EUR (Pejin Stokić & Bajec, 2020).

4.3. Chosen Definitions and Features

4.3.1. Definition of Low-Income Household Groups

Stemming from the points expressed in the previous paragraphs, it was decided to define the first decile of the income spectrum as low-income household groups. The first decile represents people having the least economic capabilities and resources. Whereas energy poverty is not a purely economic issue, it has been discussed in the previous paragraphs how the first decile is always more hit by energy poverty indicators compared to the rest of the population. In 2019, the average income in the first decile per consumption unit was 11,703 RSD, corresponding to roughly 99 EUR per month (Social Inclusion and Poverty Reduction Unit, 2021). This value is below both the "at-risk-of-poverty" threshold of 141.40 EUR and the income cap to be eligible for the tariff reductions of 125 EUR (14645 RSD) (Pejin Stokić & Bajec, 2020). Additionally, previous studies analysing the impact of policies on low-income household groups were found in the literature defining the latter as households belonging to the first income decile (Rogulj et al., 2022). Therefore, throughout the rest of the report, low-income household groups will be considered as those belonging to the first income decile.

4.3.2. Typology of Utilised Indicators

For the following study it was decided to consider only objective indicators. Objective indicators were defined as those that analyse expenditure rates or shares, constructed on financial data concerning the spending and earnings of households (Tirado Herrero, 2017). Even though the financial sphere is not the only one affecting energy poverty, it is still the most prominent one, with low income being regarded as the principal cause for energy poverty (Santamouris, 2016; Ürge-Vorsatz & Tirado Herrero, 2012). Furthermore, economic data related to energy expenses is the most easily accessible one, especially in countries not presenting a state-of-the-art working framework related to energy poverty. Hence, the great popularity and use of objective indicators. Actual energy expenditure rates will be utilised, however not related to the population average but rather to the first income decile average. Indeed, the goal of this study is to see how different policies would affect the low-income groups. In line with that train of thought, actual economic indicators will be considered when analysing the effects of policies on low-income groups.

Objective indicators were not chosen as to represent and better delineate energy poverty figures in Serbia, but rather to understand the effect that different policies would have on countering energy poverty in Serbia. To have a better understanding of how energy poverty affects different straits of society, a combination of both actual and required, objective and subjective indicators would be suggested. However, in this case more emphasis is put on understanding the consequences of policies on low-income groups. These will be analysed more from an economic perspective, and thus purely economic actual indicators will be insightful. The energy prices and final energy consumption will be the two main indicators analysed. The former directly affects citizens, either by lowering or increasing energy expenditures; whereas the latter affects both the citizens and the environment, as lower consumption is directly related to lower emissions. It must be noted that energy expenditures will be related to equivalised consumption units within the household rather than the latter itself. This allows to avoid the bias related to economies of scale, as energy expenditure is not strictly linear and proportional per house member (Tirado Herrero, 2017).

5. MODEL SIMULATION

5.1. Introduction

To better understand how different policies would affect low-income groups in Serbia, it was decided to perform simulations for each policy (scenario) utilising a linear and static model. The tool utilised to perform these simulations will be Microsoft Excel. Whereas several tools to simulate climate policies exist, MS Excel was chosen as most of the data found was compatible with the latter. The data was gathered from the Eurostat repository and the Household Budget Survey (HBS) for Serbia in 2019. The latter was the most recent HBS available (Statistical Office of the Republic of Serbia, 2020). The performed simulation will be of a static nature as static data from 2019 will be utilised. It must be noted that the most recent publicly available projections outlined by the Ministry of Mining and Energy for Serbia were performed by utilising static data from 2010 (Ministry of Mining and Energy, 2016). The simulated time horizon will be from 2019 (baseline year) to 2050, as this represents the year considered in most long-term plans, targets and projections (European Commission, 2021b; Ministry of Mining and Energy, 2022a).

A few remarks with regards to the employed simulation model need to be expressed. Firstly, since it utilises static and linear data, non-linear behaviours will not be visible. Whereas MS Excel as a tool has been utilised throughout the literature by various institutions as previously mentioned, the type of data and simulations being developed constitute a big difference. In this specific case, behaviours such as energy price trends or the final energy consumption will be represented linearly, which in real life is not the case as these might be affected by various factors. More sophisticated models are present in the literature and have been employed by different institutions. The European Commission et al. (2021), when delineating its EU Reference Scenario 2020, applied a combination of models, interlinking technical and economic methodologies. Nonetheless, these are all very sophisticated software not easily accessible. Additionally, the utilisation of such model for the problem at hand would be overwrought. Hence, even though the model being employed is a static and linear one, not offering a high level of computational abstractness, for the issue at hand, seeing also the past literature (e.g., Ban et al., 2021; Ministry of Mining and Energy, 2021d; Rogulj et al., 2022), was deemed as particularly applicable.

5.1.1. Analysis of the Status Quo

Several insights can be found analysing the energy distribution by end use and the related expenses. Firstly, it becomes clear that space heating is the main energy end-use (Figure 2), representing alone 61% of final energy consumption. For comparison, “electric appliances and lighting”, which was the second largest energy end-use, represented only 17% of final energy consumption. Not surprisingly, the same pattern could be found when analysing the costs related to energy end-uses (Figure 3). Thereafter, the energy consumption and related costs per type of fuel were analysed. Electricity was found to be the main type of fuel utilised followed by biomass and district heating; however, with the former two representing much larger shares compared to the latter (Figure 4). Once again, the same pattern was maintained with regards to the related costs (Figure 5). However, it could be noticed how district heating represented a larger share of expenses compared to consumption, and the other way around for coal. This is due to the respectively high and low costs of district heating and coal. Figure 6 gives an overview of the distribution of fuels and their consumption across different energy end-uses. For a detailed overview of all consumptions and costs, please consult Section A.1 of the Appendix. For a more detailed analysis of the distribution of fuels per single end-use, please consult Figures 11, 12, 13 of the Appendix (space cooling and "electric appliances and lighting" are not shown as these are purely electricity-fuelled).

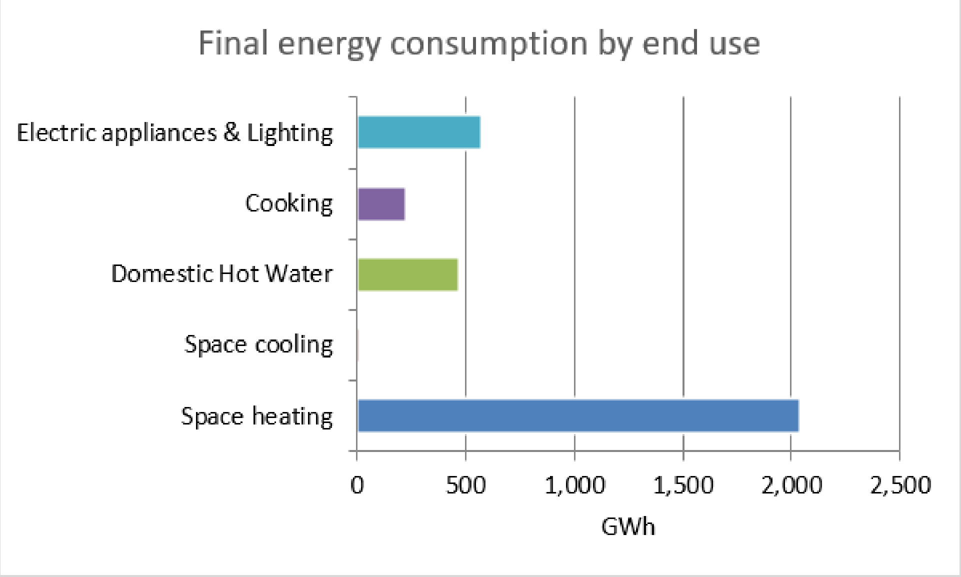


Figure 2: Final energy consumption by end-use.

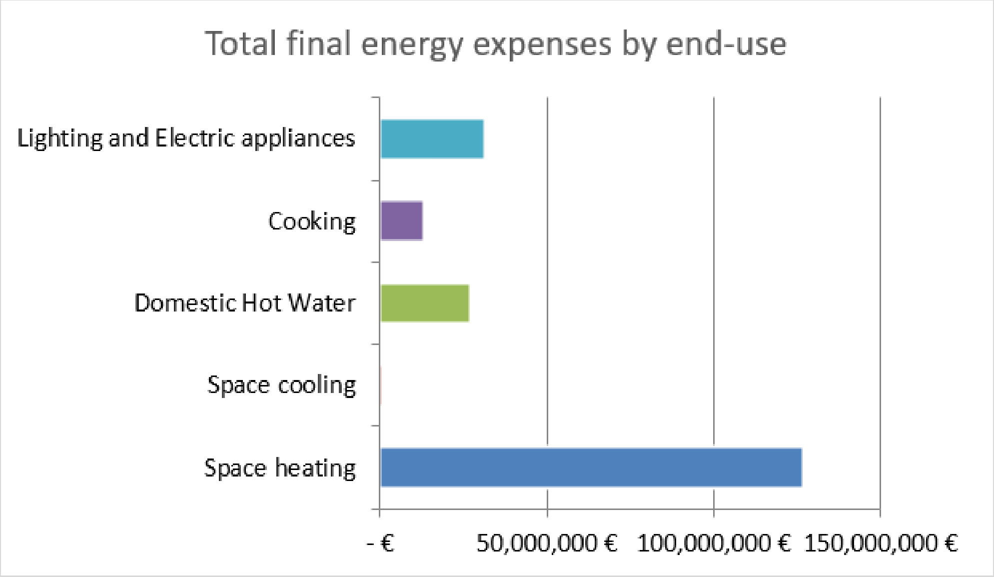


Figure 3: Energy related costs per end-use.

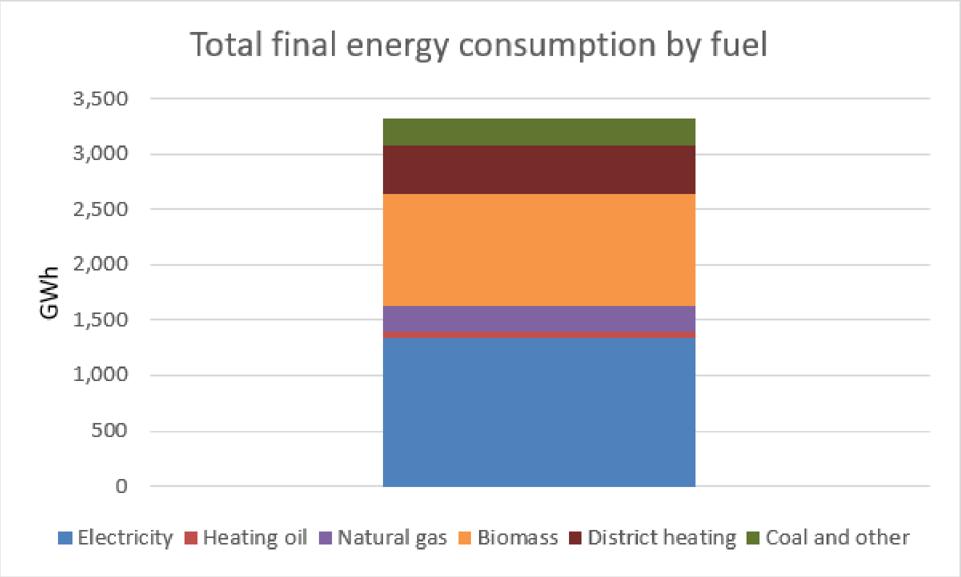


Figure 4: Share of fuels in Final Energy Consumption.

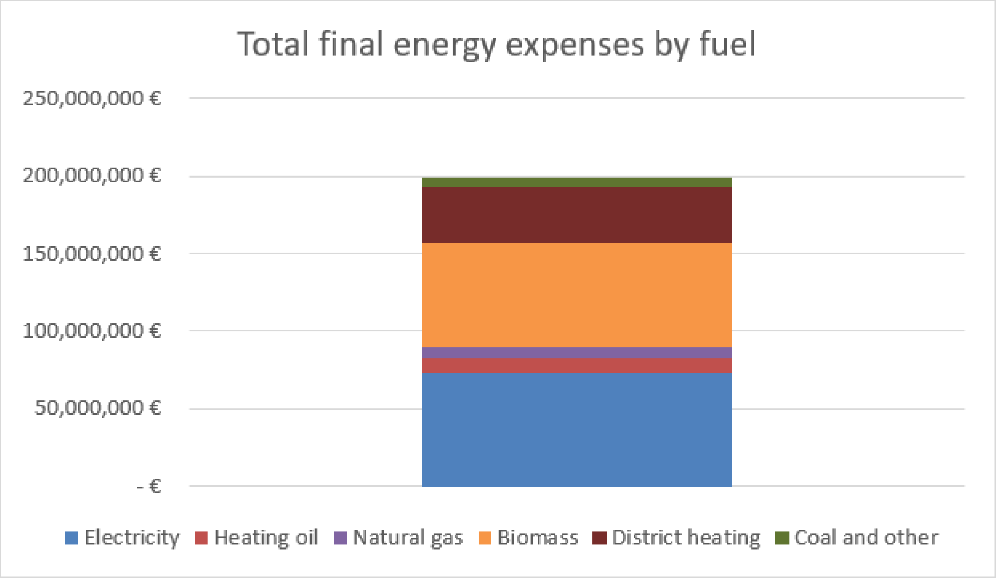


Figure 5: Share of fuels in final energy expenses.

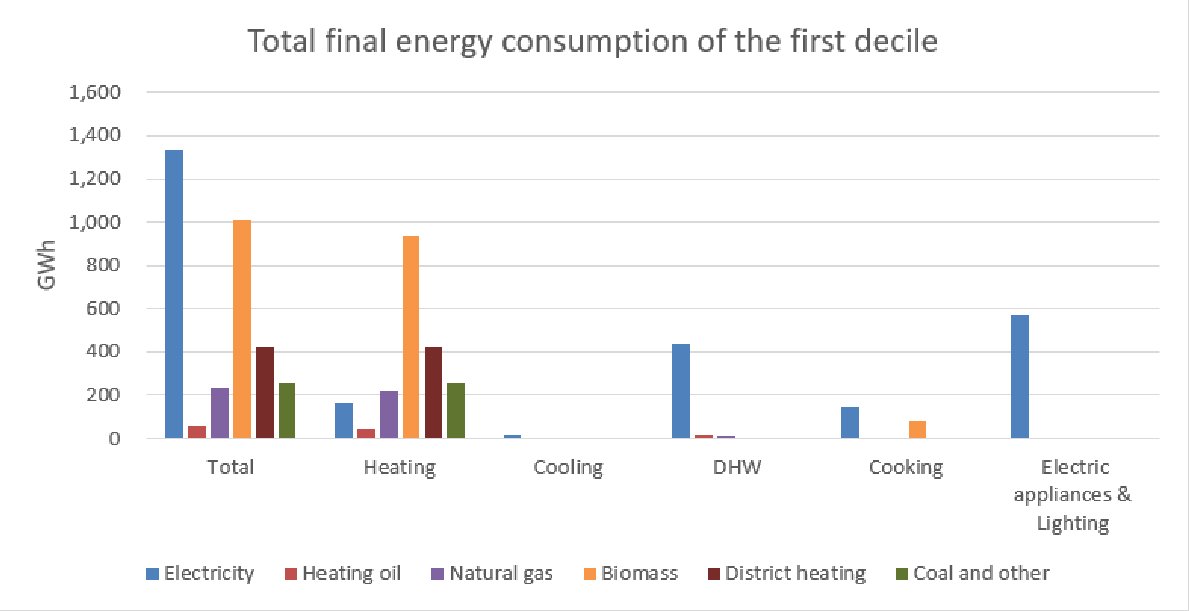


Figure 6: Overview of the distribution of fuels and their consumption by energy end-use.

5.2. Suggested Policy Measures

The outlined and tested policies corresponding to the different simulation scenarios were delineated considering both EU and national targets in the energy sector. The baseline scenario was developed to give an insight on how the situation would keep developing maintaining the 2019 energy characteristics, but also to compare the developed scenarios and provide an idea on the implied energy and monetary savings per policy. All three policies were developed considering the envisioned changes and updated targets expressed in the latest EU energy package, namely the Fit for 55 package. Indeed, each delineated policy tackles aspects mentioned both in updated EU energy directives and energy targets suggested by the Ministry of Mining and Energy.

The first scenario considered the implementation in Serbia of a carbon pricing system, similar to the EU-ETS. As mentioned in Section 3.2, Serbia has not yet implemented any form of emissions pricing or trading scheme. Meanwhile, in line with the objectives set in the Fit for 55 package, the EU proposed to expand the EU-ETS to both the transport and buildings sector (European Commission, 2021b), and thus such a scenario was considered for Serbia. The second delineated scenario considered the gradual phasing out of fossil fuel boilers. It was assumed that heating oil and coal would be phased out in 2030 and natural gas in 2040, with these heating systems being substituted by more efficient heat pumps. Boilers have an average lifetime of 20 years; hence, to reach carbon neutrality by 2050, the sale and implementation of these would have to be phased out by 2030. The third scenario considered the implementation of Minimum Energy Performance Standards (MEPS) in the buildings sector, as to achieve energy class E in 2035. It is assumed that 75% of total low-income dwellings (185,209) will need to be refurbished by 2035. Thereafter, it is assumed that all refurbished dwellings will be upgraded to energy class D in 2040.

5.3. Best Performing Policy

Scenario 3 yielded the best results from an energy consumption perspective. As can be seen in Figure 7, starting from approximately the year 2035, this policy generated the lowest FEC. Interestingly, Scenario 1, namely applying an emissions pricing/trading scheme in Serbia, was the best performing policy for a period of approximately 10 years, from 2025 to 2035. However, the initial impact this policy brought proved to be unsustainable. Indeed, this policy only reduced expenses due to the increased costs resulting from the implementation of such system. Nonetheless, after experiencing the initial shock, energy prices kept on increasing as usual and so did the consumption. The ETS has never been intended as a policy that could single-handedly improve the energy efficiency situation, but rather as a policy to be coupled with others (European Commission, 2021c,d). It must be also noted that ETS2 prices were applied to Serbia, and that these could be deemed as unrealistic and/or too expensive. In addition, the ETS system was applied directly to the households, whereas in reality such a system would be different from the existing one; more upstream and targeting fuel-suppliers rather than end-consumers. On the other hand, with a complete refurbishment of buildings, equally spread between the various sources of fuel, the reduction in consumption is more constant. The slope of the consumption line becomes less steep after 2045, namely when all the buildings have been refurbished. However, this is completely normal and expected. Indeed, once improved, the buildings will be more efficient and thus consume less energy, nonetheless this reduction in consumption will never equal the initial shock due to the refurbishment of the whole buildings sector.

Scenario 3 yielded the best results also from an energy expenses perspective. The MEPS policy produces the lowest energy expenses constantly throughout almost the whole analysed time period (Figure 8). Indeed, a more energy efficient building will consume less and thus reduce expenses as expected. On the other hand, Scenario 1 manages to reduce expenses only initially, since after the implementation of the trading system these keep on increasing following the energy price trends. Considering that in Scenario 1 the FEC kept on decreasing throughout the simulation period, this further goes to show that such reduction was purely due to the increasing costs and thus rationing of energy consumption, rather than any other factors. When considering Scenario 2, it can be seen how the reduction in expenses is closely related to the phasing out of fossil fuels, namely in 2030 and 2040. It must be noted that, even though Scenario 3 presents the lowest energy expenses values, and these keep on decreasing steadily throughout all the refurbishment period (2030-2040), these mildly increase after 2040. This is purely due to the increasing energy prices. In fact, in this scenario, it is considered that the distribution of fuels will remain the same, without envisioning any phase out. This means that solid fuels will continue to be utilised in buildings up until 2050. These would be consumed in a lower quantity but nonetheless would represent high prices in the energy market.

Scenario 3 presents the highest implementation costs out of all the analysed scenarios. Namely, a total of 2775 million euros spread over 15 years. Nonetheless, the envisioned refurbishment prices per building were assumed considering EU standards, and thus these could be actually lower for Serbia. The phase out of fossil fuel boilers would cost a total of 513 million euros spread over 10 years. Whereas such costs would not be paid directly by end-users, these could result in higher energy expenses and/or taxes if not implemented correctly. However, no great changes can be achieved without proper investment. The Republic of Serbia has already invested approximately 105 million euros in the buildings sector just in the period between January and May 2021. However, it is estimated that an extra 1636 million euros of investments are needed (Energy Community, 2021). The need to invest in household energy efficiency is clear, with the European Commission having already set aside 9 billion euros as part of the Economic Investment Plan for the Western Balkans. The latter includes as its three main objectives: tripling the refurbishment rate of existing buildings, tripling energy savings in existing dwellings and finally achieving nearly zero FEC in new buildings (Energy Community, 2021). Additionally, over 35 billion euros have been delineated in the new investment plan set by the (Ministry of Mining and Energy, 2022a). Already 1.07 billion euros of state investment are envisioned only in the field of thermal energy (heat pumps) (Ministry of Mining and Energy, 2022a). In the field of energy efficiency, including the refurbishment of residential buildings, the Ministry has planned investments for a value exceeding 3 billion euros (Ministry of Mining and Energy, 2022a). Therefore, whereas Scenario 3 presents the highest implementation costs, these should be able to be sustained by applying correct measures and policies and efficient investment planning.

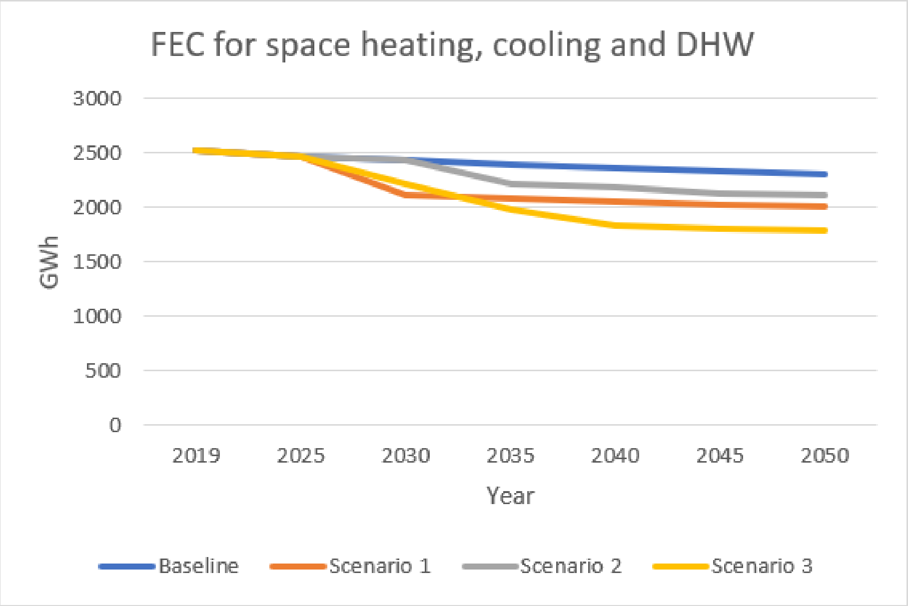


Figure 7: Graphical comparison of FEC trends over time per scenario.

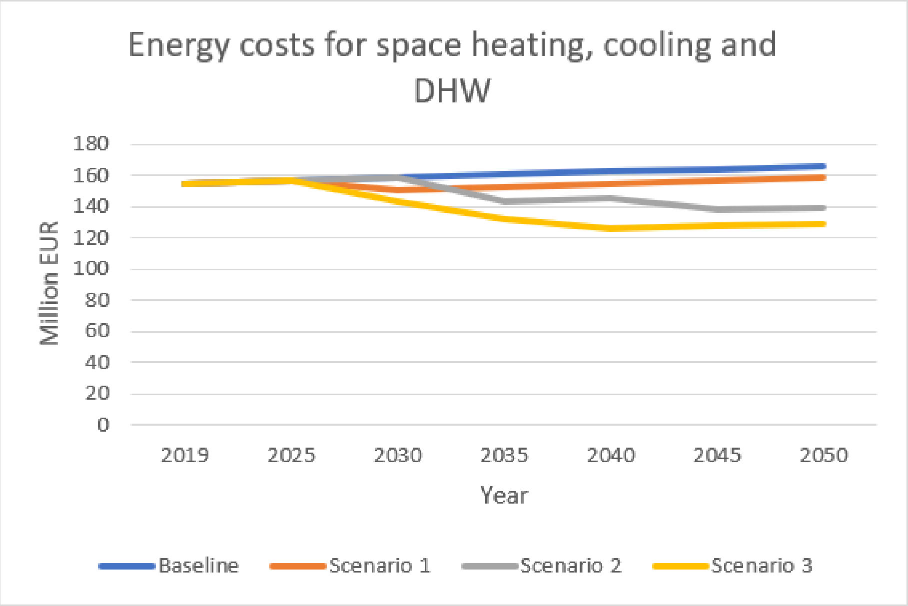


Figure 8: Graphical comparison of energy expenditures over time per scenario.

6. DISCUSSION

6.1. Policy Mechanisms Protecting Low-Income Households

The implementation of one single policy covering one specific aspect of energy poverty will not be able to substantially influence the latter, and thus specific policy combinations and instruments need to be delineated. Additionally, for one new policy to be effective and make an impact the moment it is implemented, policy mechanisms will need to be put in place to smoothen the introduction process. Energy-vulnerable consumers have been defined and recognised in Serbia, with several assistance and reduced tariff mechanisms in place to support these (Pejin Stokić & Bajec, 2020). Whereas not explicitly stated, the recipients of such services will be typically belonging to the low-income household groups and be suffering from energy poverty. However, since the implementation of this measure in 2013, constantly less households than those legally eligible have been classified as energy vulnerable. This is clearly illustrated by Figure 9, comparing the recipients of the different service and financial aid programmes. Hence, it becomes clear that the reduced tariff mechanism has not been working properly and needs to be improved. Several reasons can be outlined for this. One of these is that the dwelling size prerequisites are rather strict. In fact, the average housing space in Serbia per household in 2019 was 64 square meters for the first decile (Statistical Office of the Republic of Serbia, 2020). However, to be considered as an energy vulnerable consumer, the maximum housing space allowable is 30 square meters with an additional 14 per household member (Pejin Stokić & Bajec, 2020). The type of dwelling might also play a role depending also on the type of fuel utilised for space heating. For example, households utilising biomass will have lower consumption levels of electricity and gas compared to others. These are just two flaws within the programme that make it easier to understand why, considering that 25% of Serbians are deemed to be at risk of poverty, approximately only 1% of the population was registered as energy vulnerable (from 2016 to 2018) (Pejin Stokić & Bajec, 2020).

Reduced tariff mechanisms in Serbia present the potential to greatly ease the implementation of energy policies directed towards low-income households. However, these need to be also improved. Differentiation between utilised fuels in the households needs to be the first step. This becomes apparent when confronting the number of households covered by reduced tariffs of monthly electricity and gas bill obligations. In fact, in 2019, 74615 households obtained a reduction on their electricity bills, corresponding to approximately 9.7 million euros of annual financial expenditures (Ban et al., 2021). On the other hand, only 50 households received a reduction on their gas bills, corresponding only to approximately 500 euros of expenditures (Ban et al., 2021). Whereas this is also due to the limited gas coverage in the country, households utilising types of fuels other than electricity, such as district heating, will be inevitably advantaged (RES Foundation, 2021). Finally, it must be clearly noted that such measures are aimed at reducing the energy burden of end-consumers in the short-term, and not energy poverty in the long-term. Obligations to tackle the latter have been set out in the Law on Energy Efficiency and Rational Use of Energy and should be delineated in the NECP. Such policy mechanisms offer a vital role in complementing energy policies, focusing specifically on the lower income groups.

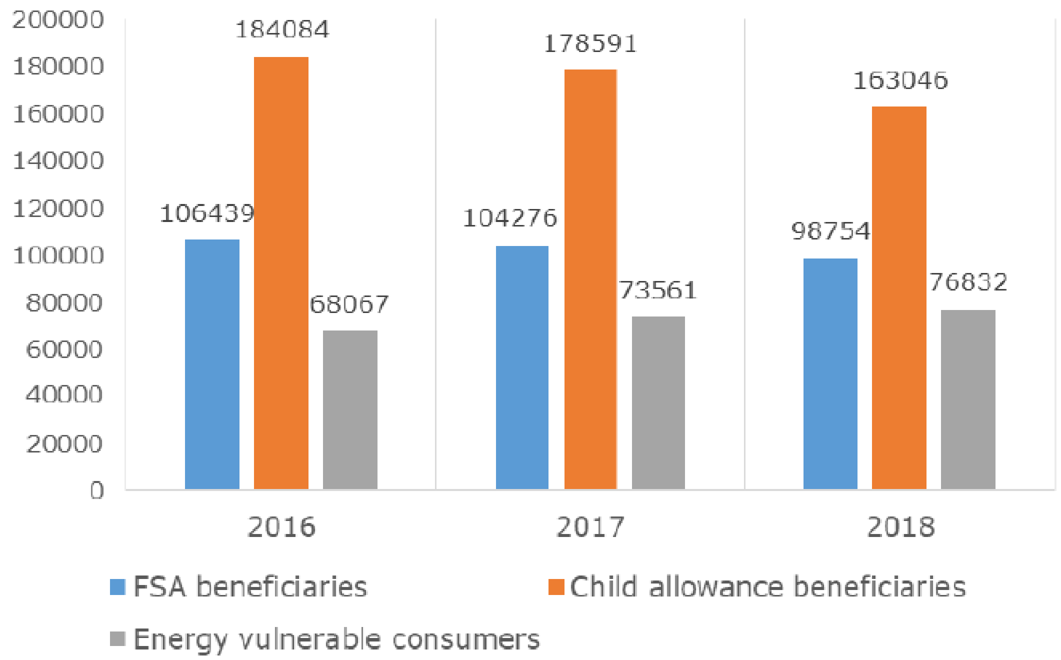


Figure 9: Comparison between number of households eligible for reduced tariff mechanism and energy vulnerable consumers in Serbia (Pejin Stokić & Bajec, 2020).

6.2. Feasibility of Proposed Measures

6.2.1. Social Feasibility

Social feasibility of energy policies can be defined in various ways. In this context, it is understood as the capacity of a policy to bring a positive social impact to one segment of the population without harming another one. Ideally, such policy would positively affect the whole population; however, in practice, it is more achievable and efficient to focus only on one segment, e.g., low-income households. Out of the three proposed measures/scenarios, two are envisioned to reduce the environmental impact, monetary expenses, and total consumption of energy within low-income households thus providing a positive social impact. In fact, Scenario 1 was found to finally increase the energy expenses of the first income decile, failing to tackle fuel providers and hampering end-consumers, causing rationing phenomena. On the other hand, both Scenario 2 and 3 managed to reduce final energy consumption and expenses while also increasing the energy efficiency of the buildings. Coupled with improved existing mechanisms to alleviate the financial burden related to energy expenses, these policies would ultimately reduce energy poverty and be welcomed by low-income groups. The only risk related to the two previously mentioned proposed policies is that these would entail slight initial increases of expenses (more pronounced for Scenario 2). Whereas these are mostly related to general increases in energy prices rather than the actual proposed measures, these could bring social turmoil if not adequately addressed and explained to the population. In fact, as also found by the HERON project (2015), two of the key social barriers are: the belief among citizens that prices will remain low and unchanged (due to previous political strategies), and the insufficient education and information related to the benefits of energy efficiency. Indeed, especially in rural areas, consumers are not aware of the additional incurred expenses and health risks due to the utilisation of outdated heating systems and housing appliances (RES Foundation, 2022). Nonetheless, it must be noted that policies trying to improve this situation have been implemented, such as the eco-labelling of energy appliances (Ministry of Mining and Energy, 2021a) (Figure 10). To conclude, in order to provide the best results possible and achieve immediate social consensus and impact, proposed policies need to be coupled not only with financial assistance programmes but also adequate, detailed and straightforward information, education and explanations with regards to energy poverty and efficiency.

FRAMEWORK REGULATION*	Household dishwashers	Fridges and freezers*	Household washing machines	Televisions	Air conditioners and fans*	Household tumble driers	Electrical lamps and luminaires	Solid fuel boilers*	Space heaters*	Water heaters & storage tanks	Domestic ovens and range hoods
🟢	🟢	🟡	🟢	🟢	🟡	🟢	🟢	🟠	🟡	🟢	🟢

🟢 Adopted and implemented 🟡 Compliance or implementation issues detected 🟠 No progress with adoption/implementation

Figure 10: Overview of the implementation of energy efficiency labelling of housing appliances in Serbia (Energy Community, 2022b).

6.2.2. Political Feasibility

Political feasibility of energy policies is hereby understood as the capacity of a given proposed policy to fit in the political, legal and institutional framework of the country. Household energy efficiency and energy poverty are indeed two aspects related to the energy transition that have been addressed in the various laws concerning the energy sector in Serbia. Indeed, there are devoted public monetary funds allocated to the cause. Nonetheless, the first proposed policy, the introduction of a carbon pricing/trading mechanism extended to the buildings sector as well, is deemed not to be politically feasible. Such proposal had been rejected even by the European Parliament in a first moment (Todorović, 2022). Therefore, in a country such as Serbia where no basic ETS is present, proposing to implement such a system already including the buildings sector would be very politically demanding and would be most certainly at least partially altered by amendments, thus incurring into bureaucratic practices such as lobbying, both by governmental and private institutions. To improve the energy transition, immediate actions are needed. The other two policies offer solutions already envisioned in governmental documents and strategies and thus are more politically feasible, with Scenario 3 being even more so compared to Scenario 2. The reason being that, to increase its energy security, Serbia has envisioned an increase of gasification levels in the mid-to-long-term (Ministry of Mining and Energy, 2022a). This could potentially create disputes over the phasing out of natural gas in 2040, as proposed by the second scenario. To conclude, the introduction of MEPS in buildings is deemed as the most politically feasible proposed policy, perfectly fitting the Serbian energy policy framework, and envisioning positive and substantial results.

7. RECOMMENDATIONS

In its last report analysing the progress made by Serbia in the various fields and clusters involved in its accession process to the EU, the European Commission evaluated Serbia as *moderately prepared* in the field of energy (European Commission, 2021a). With regards to energy efficiency specifically, important progress was recognised due to the implementation of the new Law on Energy Efficiency and Rational Use of Energy. Nonetheless, it was also expressed that "Serbia still needs to adopt further primary and secondary legislation to achieve full alignment with the Directive on the energy performance of buildings and on energy labelling" (European Commission, 2021a, (p. 112)). Therefore, the need to enhance energy efficiency in the residential sector and housing appliances in Serbia was also stressed by European institutions. Additionally, it was recommended that Serbia set ambitious targets for energy efficiency and RES in its final energy consumption when delineating its NECP (European Commission, 2021a). Taking this into account, the Main Research Question will hereby be answered.

To achieve household energy efficiency and energy poverty objectives set by the European Commission directed towards low-income groups, the Ministry of Mining and Energy is advised to implement Minimum Energy Performance Standards (MEPS) in buildings inhabited by low-income groups coupled with financial aid programmes, such as reduced-tariff mechanisms, further promoting the replacement of outdated housing devices and an improved understanding of the benefits related to improved household energy efficiency. Existing policy mechanisms aimed at alleviating the financial burden of vulnerable energy consumers need to be improved, providing more tangible energy efficiency improvements, and reaching a higher breadth of people. Additionally, promotion of energy efficient housing appliances needs to be coupled with an improved consumer education related to the benefits of more efficient devices, especially in rural areas. Previous good practices can be found in Serbia; nonetheless these need to be improved, as measures delineated for increasing energy efficiency in households obtained fewer savings than have had been planned (Ministry of Mining and Energy, 2021a). Finally, it is suggested that a 100% financing rate be used for energy efficiency improvements directed at low-income households, as these represent the most affected strait of society by energy poverty while at the same time presenting the greatest potential for improvement.

8. CONCLUSION

The present study set out with the aim to delineate optimal policy recommendations directed towards the Serbian Ministry of Mining and Energy as to achieve targets set by the European Commission in the field of household energy efficiency and energy poverty, specifically affecting low-income households. To do so, one Main Research Question and four Sub-research Questions were delineated to guide the research process. Additionally, a static linear model was utilised to simulate different scenarios pertaining to the implementation of different proposed policies. This was done to provide more quantitative backing to the selection process of the optimal suggested policy strategy. Each section aimed at answering different sub-research questions. The Main Research Question was resolved in the previous section (7). The proposed optimal policy was found to be both politically and socially feasible, having a strong social impact, as well as reducing final energy consumption, costs, and poverty among low-income households.

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APPENDIX

A1 Detailed Overview of Final Energy Consumption and Expenses

Table 1: Detailed overview of final energy consumption of low-income households in Serbia in 2019.

Total (GWh)	**Total**	**Heating**	**Cooling**	**DHW**	**Cooking**	**Electric appliances & Lighting**
Electricity	1,335	163.4	16.0	438.9	144.2	572.5
Heating oil	62	42.9		19.5		
LPG	0	0.0			0.0	
Natural gas	235	218.6		10.2	6.3	
Solar thermal	0	0.0		0.0		
Biomass	1,012	933.7			78.1	
Ambient heat	0	0.0				
District heating	427	427.0		0.0		
Coal and other	257	257.4				
Total	3,329	2,043	16	469	229	572

Table 2: Detailed overview of expenses per fuel type in low-income households in Serbia in 2019.

Final Energy Expenses per Fuel Type	
Electricity	72,889,136 €
Heating oil	9,291,888 €
LPG	- €
Natural gas	7,290,752 €
Solar thermal	- €
Biomass	66,814,943 €
Ambient heat	- €
District heating	36,294,353 €
Coal and other	7,025,026 €
Total	199,606,098 €

Table 3: Detailed overview of expenses per end-use for low-income households in Serbia in 2019.

Final Energy Expenses by End-use	
Space heating	127,062,740 €
Space cooling	874,344 €
Domestic Hot Water	27,187,277 €
Cooking	13,225,195 €
Lighting and Electric appliances	31,256,543 €
Total	199,606,098 €

A2 Share of Fuels per Individual End-use

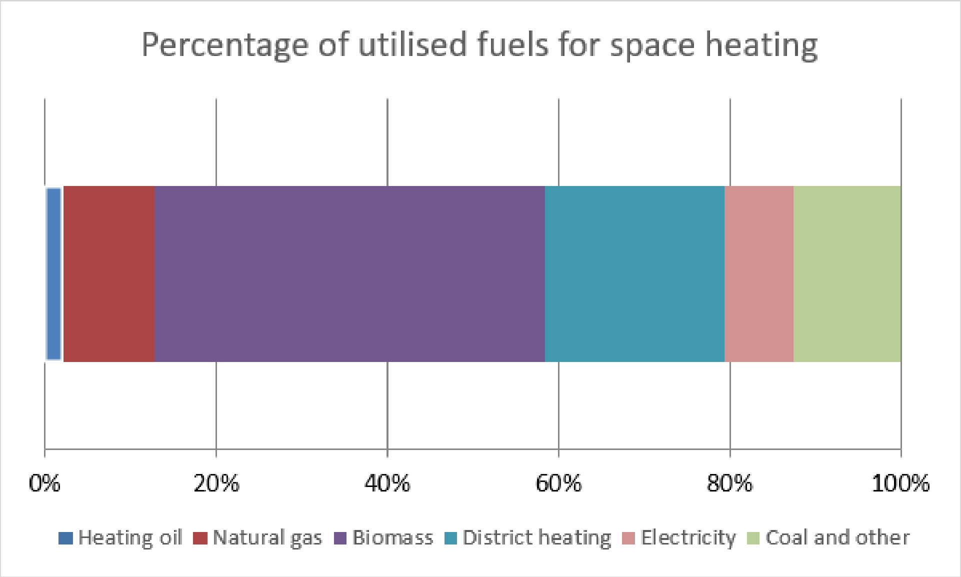

Figure 11: Distribution of fuels utilised for space heating.

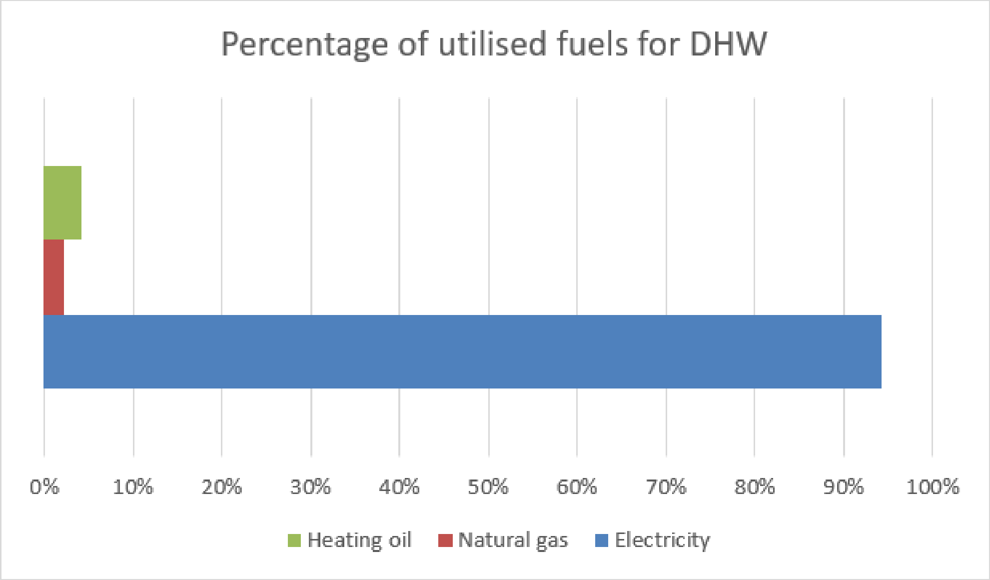

Figure 12: Distribution of fuels utilised for domestic hot water.

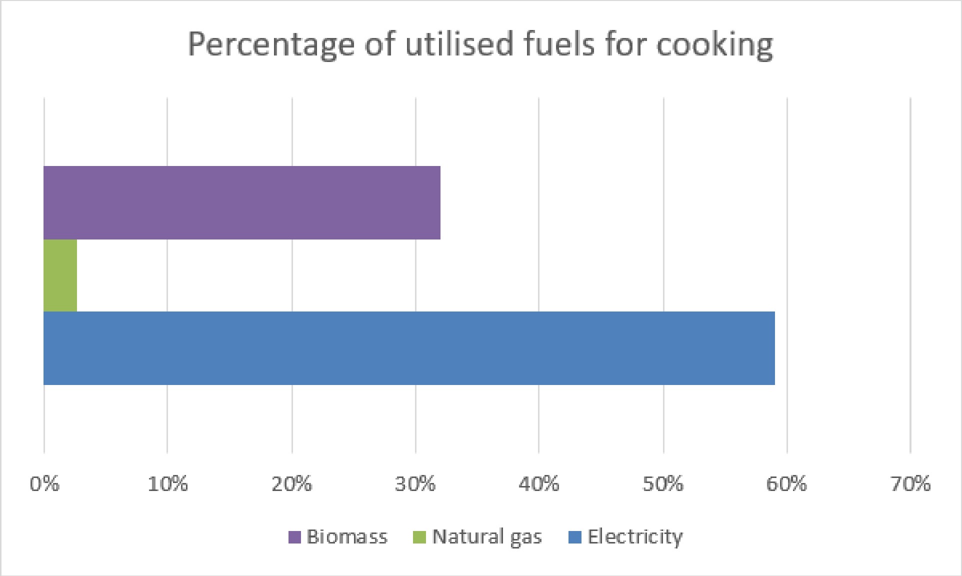

Figure 13: Distribution of fuels utilised for cooking.

A3 Detailed Overview of Energy Price Trends

Table 4: Energy price trends for Baseline, Scenario 2 and Scenario 3 in EUR/MWh as foreseen in the EU Reference Scenario 2020 (European Commission et al., 2021).

	2019	2025	2030	2035	2040	2045	2050
Heating oil	149	174	198	223	248	273	298
Natural gas	31	40	50	59	68	71	74
Coal and other	27	30	33	35	36	38	40
Electricity	55	55	55	58	60	63	67

Table 5: Energy price trends for Scenario 1 in EUR/MWh as foreseen in the EU Reference Scenario 2020 (European Commission et al., 2021).

	2019	2025	2030	2035	2040	2045	2050
Heating oil	149	174	243	286	328	367	406
Natural gas	31	40	83	106	129	143	157
Coal and other	27	30	93	119	145	166	188
Electricity	55	55	55	58	60	63	67

A4 Detailed Overview Baseline Scenario

Table 6: Detailed overview of energy consumption in GWh for Baseline Scenario.

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	37	34	32	31	29
Natural gas	219	186	164	149	137	134	131
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	159	155	150	146
Coal and other	257	245	233	227	221	215	210
Total	2043	1993	1958	1930	1906	1891	1878
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**

Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DHW)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	8	7	6	6	6
Heating oil	20	18	17	16	15	14	13
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	449	437	424	412
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	53	50	47	45	43
Natural gas	229	195	172	156	144	140	137
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	600	587	569	553
Coal and other	257	245	233	227	221	215	210
Total	2528	2474	2435	2394	2359	2330	2304

Table 7: Detailed overview of energy expenses in million EUR for Scenario 1.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	11	11	12	12	13
Natural gas	7	8	9	9	10	10	10
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	35	35	36	37
Coal and other	7	7	8	8	8	8	8
Total	155	157	159	161	163	164	166

A5 Detailed Overview Scenario 1

Table 8: Detailed overview of energy consumption in GWh for Scenario 1.

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	32	29	27	25	24
Natural gas	219	186	87	75	67	63	60
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	159	155	150	146
Coal and other	257	245	0	0	0	0	0
Total	2043	1993	1641	1623	1609	1599	1590
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DHW)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	4	3	3	3	3
Heating oil	20	18	14	13	12	11	11
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	455	443	432	418	406
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	46	42	39	36	34
Natural gas	229	195	91	78	70	66	63
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	600	587	569	553
Coal and other	257	245	0	0	0	0	0
Total	2528	2474	2112	2081	2056	2032	2011

Table 9: Detailed overview of energy expenses in million EUR for Scenario 1.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	11	12	13	13	14
Natural gas	7	8	8	8	9	9	10
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	35	35	36	37
Coal and other	7	7	0	0	0	0	0
Total	155	157	151	153	155	157	159

A6 Detailed Overview Scenario 2

Table 10: Detailed overview of energy consumption in GWh for Scenario 2.

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	37	0	0	0	0
Natural gas	219	186	164	149	137	0	0
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	60	59	133	129
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	163	163	163	183	178	203	197
Coal and other	257	245	233	0	0	0	0
Total	2043	1993	1958	1752	1735	1697	1687
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	16	16	15	15	14
Total	16	16	16	16	15	15	14
Domestic hot water (DWH)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	439	429	421	410
Natural gas	10	9	8	7	6	0	0
Heating oil	20	18	17	0	0	0	0
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	446	435	421	410

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	53	0	0	0	0
Natural gas	229	195	172	156	144	0	0
LPG	0	0	0	0	0	0	0
Biomass	934	934	934	934	934	934	934
Ambient heat	0	0	0	60	59	133	129
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	427	427	427	427	427
Electricity	618	617	615	637	622	639	621
Coal and other	257	245	233	0	0	0	0
Total	2528	2474	2435	2213	2185	2133	2111

Table 11: Detailed overview of energy expenses in million EUR for Scenario 2.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	11	0	0	0	0
Natural gas	7	8	9	9	10	0	0
LPG	0	0	0	0	0	0	0
Biomass	62	62	62	62	62	62	62
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	36	36	36	36	36
Electricity	34	34	34	37	37	40	41
Coal and other	7	7	8	0	0	0	0
Total	155	157	159	144	145	138	139

A6.1 Calculation of Implementation Costs

It was assumed that the implementation of one heat pump would cost 8000 EUR. In 2030, heating oil and coal would be phased out. These represent 15% of space heating energy consumption. Thus, it is assumed that in 15% of households a heat pump would have to be implemented. Therefore, 37,005 households multiplied by 8000 EUR yields approximately 296 million euros expenses. Similarly, in 2040, all natural gas would be phased out, representing 11% of space heating energy consumption. Again, assuming in 11% of households new heat pumps would be implemented, this results in 27,137 households multiplied by 8000 EUR and thus approximately 217 million euros.

A7 Detailed Overview Scenario 3

Table 12: Detailed overview of energy consumption in GWh for Scenario 3.

Space heating	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	43	39	32	27	24	22	21
Natural gas	219	186	146	117	100	98	96
LPG	0	0	0	0	0	0	0
Biomass	934	934	829	735	680	680	680
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	379	336	311	311	311
Electricity	163	163	144	125	113	110	107
Coal and other	257	245	207	179	161	157	153
Total	2043	1993	1737	1520	1389	1378	1368
Space cooling	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	16	16	14	12	11	11	10
Total	16	16	14	12	11	11	10
Domestic hot water (DWH)	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electricity	439	438	437	426	416	404	393
Natural gas	10	9	8	7	6	6	6
Heating oil	20	18	17	16	15	14	13
District heating	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Coal and other	0	0	0	0	0	0	0
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
Total	469	464	461	449	437	424	412
Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	62	57	49	43	38	36	35
Natural gas	229	195	154	124	106	104	102
LPG	0	0	0	0	0	0	0
Biomass	934	934	829	735	680	680	680
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	427	427	379	336	311	311	311
Electricity	618	617	595	563	540	524	509
Coal and other	257	245	207	179	161	157	153
Total	2528	2474	2213	1981	1837	1813	1790

Table 13: Detailed overview of energy expenses in million EUR for Scenario 3.

Space heating, cooling and DHW	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heating oil	9	10	10	9	9	10	10
Natural gas	7	8	8	7	7	7	8
LPG	0	0	0	0	0	0	0
Biomass	62	62	55	49	45	45	45
Ambient heat	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0
District heating	36	36	32	29	26	26	26
Electricity	34	34	33	32	32	33	34
Coal and other	7	7	7	6	6	6	6
Total	155	157	144	133	126	128	129

A7.1 Calculation of Implementation Costs

It is assumed that 75% of low-income household buildings will be refurbished, that is 185,028 households. However, 50% of these will be renovated in 2030 and the other half in 2035. Thus, in 2030, 92,514 buildings will be renovated to meet class E standards (10,000 EUR costs) and thus in total approximately 925 million euros will be spent. Same goes for 2035. Thereafter, in 2040, all these buildings will be improved to Class D, involving costs of 5,000 EUR per building. Thus, 185,028 households times 5,000 EUR yields again 925 million euros.